| L Number | Hits | Search Text | DB | Time stamp |
|---|---|---|---|---|
| 1 | 75 | determine with (polish$3 adj rate) and semiconductor | USPAT; US-PGPUB | 2002/12/18 16:54 |
| 2 | 59 | (determine with (polish$3 adj rate) and semiconductor) and planariz$5 and thickness | USPAT; US-PGPUB | 2002/12/18 16:55 |
| 3 | 30 | determine with (polish$3 adj time) and semiconductor | USPAT; US-PGPUB | 2002/12/18 16:55 |
| 4 | 22 | (determine with (polish$3 adj time) and semiconductor) and planariz$5 and thickness | USPAT; US-PGPUB | 2002/12/18 16:55 |
| 5 | 12 | ((determine with (polish$3 adj time) and semiconductor) and planariz$5 and thickness) not ((determine with (polish$3 adj rate) and semiconductor) and planariz$5 and thickness) | USPAT; US-PGPUB | 2002/12/18 16:55 |

| | Title | Current OR | Current XRef |
|---|---|---|---|
| 1 | Method and apparatus for monitoring polishing state, polishing device, process wafer, semiconductor device, and method of manufacturing semiconductor device | 451/6 | |
| 2 | Endpoint detector and method for measuring a change in wafer thickness in chemical-mechanical polishing of semiconductor wafers and other microelectronic substrates | 356/630 | |
| 3 | Polishing body, polishing apparatus, polishing apparatus adjustment method, polished film thickness or polishing endpoint measurement method, and semiconductor device manufacturing method | 451/6 | |
| 4 | Method and apparatus for controlled polishing | 451/5 | 451/287; 451/8 |
| 5 | System for real-time control of semiconductor wafer polishing | 451/10 | 451/11; 451/285; 451/41 |
| 6 | System and method for predicting software models using material-centric process instrumentation | 700/45 | |
| 7 | Forming a transparent window in a polishing pad for a chemical mehcanical polishing apparatus | 451/527 | 451/533; 451/550 |
| 8 | System for real-time control of semiconductor wafer polishing | 451/5 | 451/36; 451/8 |
| 9 | System for real-time control of semiconductor wafer polishing | 451/5 | 451/288; 451/8 |
| 10 | System for real-time control of semiconductor wafer polishing | 451/7 | 451/10; 451/41; 451/53; 451/9 |
| 11 | System for real-time control of semiconductor wafer polishing | 451/5 | 451/7; 451/8; 451/9 |

| | Title | Current OR | Current XRef |
|---|---|---|---|
| 12 | Polishing body, polishing apparatus, polishing apparatus adjustment method, polished film thickness or polishing endpoint measurement method, and semiconductor device manufacturing method | 451/6 | 451/287; 451/41; 451/526 |
| 13 | Planarizing machines and alignment systems for mechanical and/or chemical-mechanical planarization of microelectronic substrates | 451/6 | 451/10; 451/288; 451/296; 451/307; 451/41; 451/8; 451/9 |
| 14 | System for real-time control of semiconductor wafer polishing | 451/5 | 451/10; 451/287; 451/288; 451/6; 451/8 |
| 15 | System for real-time control of semiconductor wafer polishing | 451/7 | 451/288; 451/289; 451/8 |
| 16 | Endpoint detector and method for measuring a change in wafer thickness | 356/630 | |
| 17 | Method and apparatus for controlling within-wafer uniformity in chemical mechanical polishing | 451/10 | 451/11; 451/285; 451/287; 451/41; 451/54; 451/63 |
| 18 | Real-time control of chemical-mechanical polishing processes using a shaft distortion measurement | 451/6 | 451/2; 451/285; 451/287; 451/288; 451/5; 451/8 |
| 19 | System for real-time control of semiconductor wafer polishing | 451/5 | 451/10; 451/287; 451/288; 451/6; 451/8 |
| 20 | Endpoint detector and method for measuring a change in wafer thickness in chemical-mechanical polishing of semiconductor wafers and other microelectronic substrates | 356/630 | 438/16 |

| | Title | Current OR | Current XRef |
|---|---|---|---|
| 21 | Apparatus and method for in-situ monitoring of chemical mechanical polishing operations | 451/6 | 451/285 |
| 22 | Polishing apparatus and method for planarizing layer on a semiconductor wafer | 156/345.13 | 451/287 |
| 23 | System for real-time control of semiconductor wafer polishing | 451/5 | 451/288; 451/289; 451/6; 451/7; 451/8; 451/9 |
| 24 | Method and apparatus for determining endpoint during a polishing process | 451/8 | 451/41 |

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| 2 | ☐ | ☒ | US 20020071128 A1 | 20020613 | 18 |
| 3 | ☐ | ☒ | US 20020042243 A1 | 20020411 | 46 |
| 4 | ☐ | ☒ | US 20020037681 A1 | 20020328 | 25 |
| 5 | ☐ | ☒ | US 20010041501 A1 | 20011115 | 26 |
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| 8 | ☐ | ☒ | US 20010016466 A1 | 20010823 | 26 |
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| 11 | ☐ | ☒ | US 6464560 B2 | 20021015 | 26 |

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| 1 | | Ishikawa, Akira et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2 | | Doan, Trung T. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3 | | Ihsikawa, Akira et al. | ☒ | ☐ | ☒ | ☐ | ☐ | ☐ | ☐ |
| 4 | | Gitis, Norm et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5 | | Sandhu, Gurtej S. et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 6 | | Mendez, Rafael et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 7 | | Birang, Manoocher M.B. et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 8 | | Sandhu, Gurtej S. et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 9 | | Sandhu, Gurtej S. et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 10 | | Sandhu, Gurtej S. et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 11 | | Sandhu, Gurtej S. et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

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| 14 | | Sandhu, Gurtej S. et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 15 | | Sandhu, Gurtej S. et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 16 | | Doan, Trung T. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 17 | | Campbell, W. Jarrett et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 18 | | Li, Leping et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 19 | | Sandhu, Gurtej S. et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 20 | | Doan, Trung T. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

| | Retrieval Classif | Inventor | S | C | P | 2 | 3 | 4 | 5 |
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| 21 | | Birang, Manoocher et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 22 | | Kodera, Masako et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 23 | | Sandhu, Gurtej S. et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 24 | | Takahashi, Tamami et al. | ☒ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

DOCUMENT-IDENTIFIER: US 20010041501 A1

TITLE: System for real-time control of semiconductor wafer polishing

---------- KWIC ---------

[0009] A compounding problem associated with polishing semiconductor wafers is
the inability to monitor polishing conditions in a effort to detect and correct
the above inherent polishing problems as they occur. It is common to conduct
numerous pre-polishing measurements of the wafer before commencement of the
polishing process, and then conduct numerous similar post-polishing
measurements to determine whether the polishing process yielded the desired
topography, **thickness,** and uniformity. However, these pre- and post-polishing
measurements are labor intensive and result in a low product throughput.

[0036] In another aspect of the invention, a system for polishing a
semiconductor wafer comprises a wafer polishing assembly for polishing a face
of a semiconductor wafer at a **polishing rate** and a polishing uniformity, the
wafer polishing assembly including a platen rotatable about a first axis, a
polishing head which supports the semiconductor wafer for rotation about a
second axis, and a polishing head displacement mechanism which moves the
polishing head and wafer across the platen, the wafer polishing assembly having
a plurality of controllable operational parameters that upon variation change
the **polishing rate** and polishing uniformity; a controller operably coupled to
the wafer polishing assembly for monitoring and managing in

situ at least one
of the operational parameters of the wafer polishing assembly; a processor
operably coupled to the controller for determining a set of desired operational
parameters based on the monitored operational parameters and outputting control
information indicative of the desired operational parameters to the controller,
the controller adjusting in situ at least one of the operational parameters of
the wafer polishing assembly in response to the control information from the
processor to effectuate a new **polishing rate** and a new polishing uniformity as
the wafer polishing assembly continues to polish the face of the semiconductor
wafer; and a detector operating on the wafer and communicating with the
processor to **determine** whether polishing of the wafer is complete.

[0050] Wafer polishing assembly 12 has a film **thickness** measurement device 60
for measuring topography of the wafer face during polishing. Film **thickness**
measurement device 60 is preferably implemented in the form of a laser
interferometer measuring apparatus which employs interference of light waves
for purposes of measurement. The laser interferometer measuring apparatus
includes light transmitter/receiver units 62 provided at the surface of the
platen subassembly 16 which transmit light at the wafer face and collect
reflections therefrom. The laser apparatus also includes laser source and
controller 64 which is optically coupled to units 62. The laser apparatus is
configured to measure thicknesses and contour of films and materials on the
wafer face. Apart from the laser apparatus, this invention also contemplates
other techniques and systems that can be used as a film **thickness** measurement
device including a system for measuring capacitance change

during wafer polishing, a device for detecting friction change at the wafer surface, and an acoustic mechanism for measuring wave propagation as films and layers are removed during polishing.

[0055] Controller 72 is connected to slurry supply means 50 via connector 79 to monitor and adjust slurry composition and flow rate. Controller 72 is coupled to temperature sensor 90 via connector 78 to receive feedback information concerning temperature of the polishing environment and wafer surface. Connector 81 conveys control signals and feedback information between controller 72 and film **thickness** measurement device 60.

[0057] Controller 72 works in conjunction with film **thickness** measurement device 60 to determine the polishing rates and uniformity across the wafer during real-time evaluations. This information is passed to processor 74 which then generates a map indicative of the polish rates and/or uniformity across the semiconductor wafer face for use in adjusting system operational parameters. Preferably, this map is generated on a periodic basis. In one embodiment, such mapping is performed using the techniques disclosed in U.S. Pat. No. 5,196,353, issued to Sandhu et al., assigned to the assignee of the present invention, and incorporated herein by reference. The technique disclosed in U.S. Pat. No. 5,196,353 involves using an infrared camera to detect infrared waves emitted from a wafer and correlating this information to the heat of various points on the wafer. Using this arrangement, the relative temperature at any point on the wafer is detected and mapped, and an infrared image of the surface of the wafer is developed.

[0063] More particularly, in the illustrated embodiment, the means for directing acoustic waves at the wafer comprises an acoustic wave transducer 302 connected to the controller 72 (and thus to the processor 74) via line 306, and the means for receiving reflected acoustic waves comprises an acoustic wave receiver 304 mounted to receive acoustic waves reflected from the wafer and connected to the controller 72 (and thus to the processor 74) via line 308. The transducer 302 converts an applied electrical voltage into a mechanical strain producing an acoustical wave. In one embodiment, the transducer 302 comprises a piezoelectric transducer, such as a thin film transducer, that converts a voltage into an acoustical wave. Similarly, in one embodiment, the receiver 304 comprises a piezoelectric receiver, such as a thin film receiver, that converts a reflected acoustic wave into a voltage. In the illustrated embodiment, the acoustic waves are directed at the backside of the wafer. In an alternative embodiment (not shown), the waves are directed at the front of the wafer by causing the polishing head displacement mechanism 76 to move the wafer to a location where an acoustic transducer and receiver can act on the front of the wafer. This is, for example, off the platen or at predetermined location on the platen where the transducer and receiver are located. The **thickness** of the wafer and the oxide layer on the wafer is determined by the processor 74 which analyzes the acoustic wave that is sent by the transducer 302 and the acoustic wave that is received by the receiver 304. More particularly, **thickness** is determined from the round trip time interval between the launch of an acoustical wave by the transducer 302 and the reception of the reflected wave by the receiver 304, and the speed of the

acoustic waves through the layers of the wafer.

[0064] The amplitude as well as round trip time of the acoustic waves will change after a film has been completely removed and a different film layer has been contacted. An end point that corresponds to the interfaces of a different film of multiple layers of stacked films can be detected, as well as the end point of an oxide layer. In one embodiment, the planarization of a film is measured in real time by measuring a film **thickness** at several locations on the wafer.

US-PAT-NO: 6276989

DOCUMENT-IDENTIFIER: US 6276989 B1

TITLE: Method and apparatus for controlling within-wafer uniformity in chemical mechanical polishing

---------- KWIC ---------

Chemical mechanical polishing (CMP) is a widely used means of planarizing silicon dioxide as well as other types of layers on semiconductor wafers. Chemical mechanical polishing typically utilizes an abrasive slurry disbursed in an alkaline or acidic solution to **planarize** the surface of the wafer through a combination of mechanical and chemical action. Generally, a chemical mechanical polishing tool includes a polishing device positioned above a rotatable circular platen or table on which a polishing pad is mounted. The polishing device may include one or more rotating carrier heads to which wafers may be secured, typically through the use of vacuum pressure. In use, the platen may be rotated and an abrasive slurry may be disbursed onto the polishing pad. Once the slurry has been applied to the polishing pad, a downward force may be applied to each rotating carrier head to press the attached wafer against the polishing pad. As the wafer is pressed against the polishing pad, the surface of the wafer is mechanically and chemically polished.

As semiconductor devices are scaled down, the importance of chemical mechanical polishing to the fabrication process increases. In

particular, it becomes
increasingly important to control and minimize within-wafer topography
variations. For example, in one embodiment, to minimize spatial variations in
downstream photolithography and etch processes, it is necessary for the oxide
**thickness** of a wafer to be as uniform as possible (i. e., it is desirable for
the surface of the wafer to be as planar as possible.)

Referring to FIG. 3, the center-to-edge radial polish rate profile for a batch
of five wafers is shown. It is contemplated that the pre-polish and
post-polish **thickness** of the polished layer may be measured at a plurality of
radial positions along the wafer. Once measured, the polish rate at these
radial positions may be determined by comparing the post-polish and pre-polish
measurements and both quadratic and linear polynomials may be fit to the polish
rate profile. In one embodiment, the state of the polishing tool 20 (e.g.,
center-fast, center-slow, etc.) may be characterized by the slope of the linear
curve fit (ie., polish rate slope.) For example, a positive slope of the radial
polish rate profile indicates center-slow polishing while a negative slope
indicates center-fast polishing.

An input variable of the polishing tool 20 may be selected that has a strong
and predictable impact on the controlled variable, (e.g., polish rate slope.)
Moreover, it is important that manipulation of the selected input variable not
significantly impact the mean polish rate (i.e., the input variable must
control surface non-uniformity of the wafer without substantially affecting the
mean **thickness** of the polished layer.) In one embodiment, the input variable is
the oscillation length of the polishing arms 36 (ie., arm oscillation length.)

As stated above, it is important that manipulation of the arm oscillation length not substantially impact the mean polish rate (i.e., it is desirable for the input variable to control surface non-uniformity without substantially affecting the mean **thickness** of the polished layer.) Those skilled in the art will appreciate that mean polish rate ##EQU1##

Referring to FIG. 6, an exemplary system 72 for controlling the polishing tool 20 is shown. The exemplary system 72 includes a first and second metrology tool 76, 80 for measuring pre-polish **thickness** and post-polish **thickness** of process layers (e.g., dielectric layers, metal layers, etc.), respectively. Those skilled in the art will appreciate that although two metrology tools 76, 80 are shown, a single metrology tool may be used to perform both pre-polish and post-polish **thickness** measurements. The two metrology tools 76, 80 may be coupled to the polishing tool 20, and a suitable metrology tool 76, 80 for many applications is the Optiprobe.RTM. metrology tool manufactured by Therma-Wave, Inc. The system further includes a controller 84 coupled to the polishing tool 20. The controller 84 may receive pre-polish and post-polish **thickness** measurements from the metrology tools 76, 80, which may be used to control the polishing tool 20. Moreover, the controller 84 may be implemented using a variety of software applications. For example, the controller may be a model predictive controller implemented using MatLab Optimization Toolbox.RTM. routines.

At block 100, a first measurement may be made of the wafer layer **thickness** to determine the pre-polish surface non-uniformity of the wafer. As was

illustrated above, the pre-polish **thickness** of a process layer may be compared with the post-polish **thickness** the process layer to **determine** the state of the polishing process (e.g., center-fast, center-slow, etc.) For example, in one embodiment, the control variable is **polish rate** slope, and the **polish rate** slope is determined by measuring the pre-polish and post-polish **thickness** of the process layer at a plurality of radial points. In one embodiment, the **thickness** of the process layer is measured using an ellipsometer at 9 radial sites and a best-fit line is used to determine the pre-polish surface non-uniformity of the process layer.

Referring back to FIG. 7, the first lot of wafers is polished, at block 124. Once the first lot of wafers is polished, at block 128, a second measurement of the process layer **thickness** may be made to determine the polishing state of the polishing tool 20. As described above, rather than measuring each wafer in the first lot, a representative group of wafers may be measured from the first lost, and the control variable for the first lot may be determined from the measurements of the representative group. For example, in one embodiment, a lot of wafers is comprised of 25 wafers, and a representative group from the lot is comprised of 5 wafers. To **determine** the state of the polishing tool 20, the second measurement (e.g., post-polish **thickness** of the process layer) may be compared with the first measurement (eg., pre-polish **thickness** of the process layer), and in one embodiment, the **polish rate** slope of the process layer may be determined.

9. The method of claim 1, wherein the control variable is polish rate slope, and the polish rate slope is determined by measuring a

pre-polish and a
post-polish **thickness** of the process layer of the first lot of wafers at a
plurality of radial positions and comparing the pre-polish measurements with
the post-polish measurements at substantially the same radial positions.

US-PAT-NO: 6213846

DOCUMENT-IDENTIFIER: US 6213846 B1

TITLE: Real-time control of chemical-mechanical polishing processes using a shaft distortion measurement

---------- KWIC ---------

In film removal processes, it is extremely important to stop the process when the correct film **thickness** has been removed (that is, when the endpoint has been reached). In a typical CMP process, a film is selectively removed from a semiconductor wafer by rotating the wafer against a polishing pad (or moving the pad against the wafer, or both) with a controlled amount of pressure in the presence of a slurry. Overpolishing (removing too much) of a film renders the wafer unusable for further processing, thereby resulting in yield loss. Underpolishing (removing too little) of the film requires that the CMP process be repeated, which is tedious and costly. Underpolishing may sometimes go unnoticed, which also results in yield loss.

In a number of CMP processes, it is necessary to measure the **thickness** of the layer to be removed and the **polishing rate** for each wafer, in order to **determine** a desired polishing time. The CMP process is simply run for this length of time, and then stopped. Since many different factors influence the polishing rate, and the polishing rate itself can change during a process, this approach is far from satisfactory.

US-PAT-NO: 5948205

DOCUMENT-IDENTIFIER: US 5948205 A

TITLE: Polishing apparatus and method for planarizing layer on a semiconductor wafer

---------- KWIC ---------

In an attempt to bring the rate of polishing the test piece closer to the actual rate of polishing devices on the manufacturing line, more than one and preferably a considerably large number of test pieces are used to **determine** an optimum **polishing rate**. Such a measure, however, entails an increase in the manufacturing cost due to a higher material cost for test pieces and a reduction in the operating hours of the manufacturing facilities, making it even more impractical.

By utilizing this relationship, it is now possible to measure the friction caused between the layer being polished and a turntable carrying a polishing slurry during the polishing operation, **determine** the rate of polishing the layer from the measured friction, **determine** the extent of polishing of the layer by integrating the **polishing rate** with time and terminate the polishing operation upon coincidence of the extent of polishing of the layer and a predetermined value. Therefore, it is possible to provide a method of easily and accurately controlling the extent to which the device is polished.

US-PAT-NO: 5830041

DOCUMENT-IDENTIFIER: US 5830041 A

TITLE: Method and apparatus for determining endpoint during a polishing process

---------- KWIC ---------

The electric current of the first motor 6 is detected by the first motor current detector 8, and the detected electric current signal is sent to the signal processing device 10. In the signal processing device 10, the electric current signal is processed to eliminate noise and further to **determine** the reference time when the uneven surface is polished to a flat surface, and the polishing time from the reference time is calculated on the basis of the **polishing rate** which has been input to the signal processing device 10. The signal processing device 10 sends an endpoint signal to the controller 11 when the calculated polishing time has elapsed, and the controller 11 stops the polishing process of the polishing apparatus.